



CLOUD HYDROINFORMATION SYSTEM AND WEB SERVICES

Blagoj Delipetrev

Promoter

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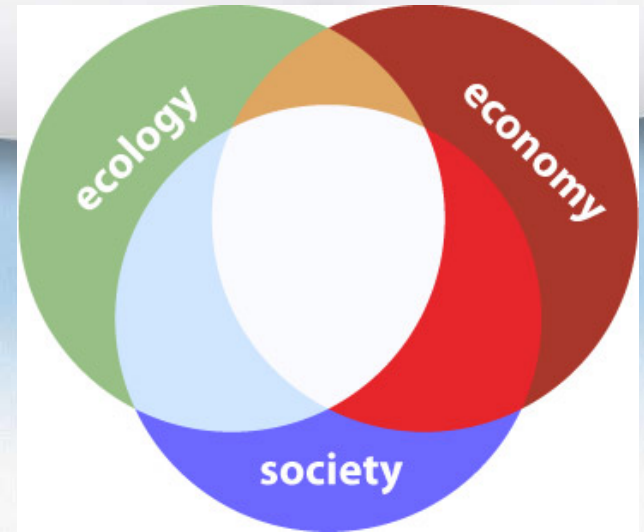
Supervisor

Andreja Jonoski (MSc, PhD)

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Introduction

Successful water management needs long term planning concerning technical, economic, social and ecological aspects.



The complexity of integrated water management requires development of hydroinformatics systems (including Decision Support Systems – DSSs) that enable efficient and equitable distribution of water resources across all water users and functions.

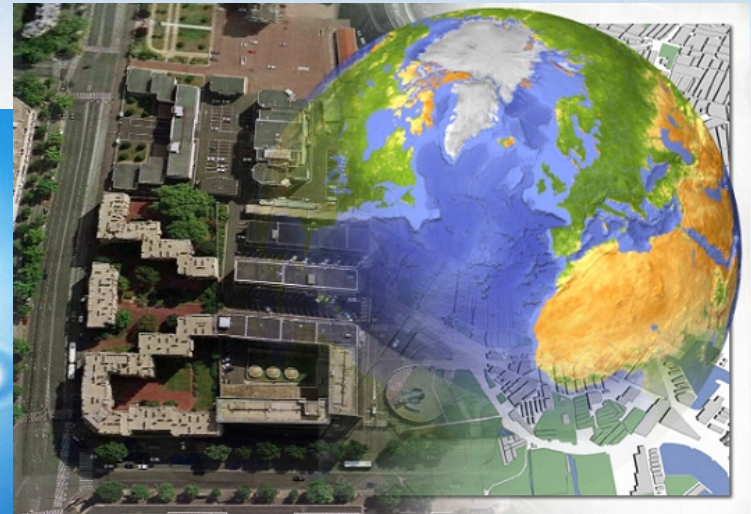
Starting point is to develop a hydro information system

Motivation

Network is the computer !



Web based GIS (Geographic Information systems)

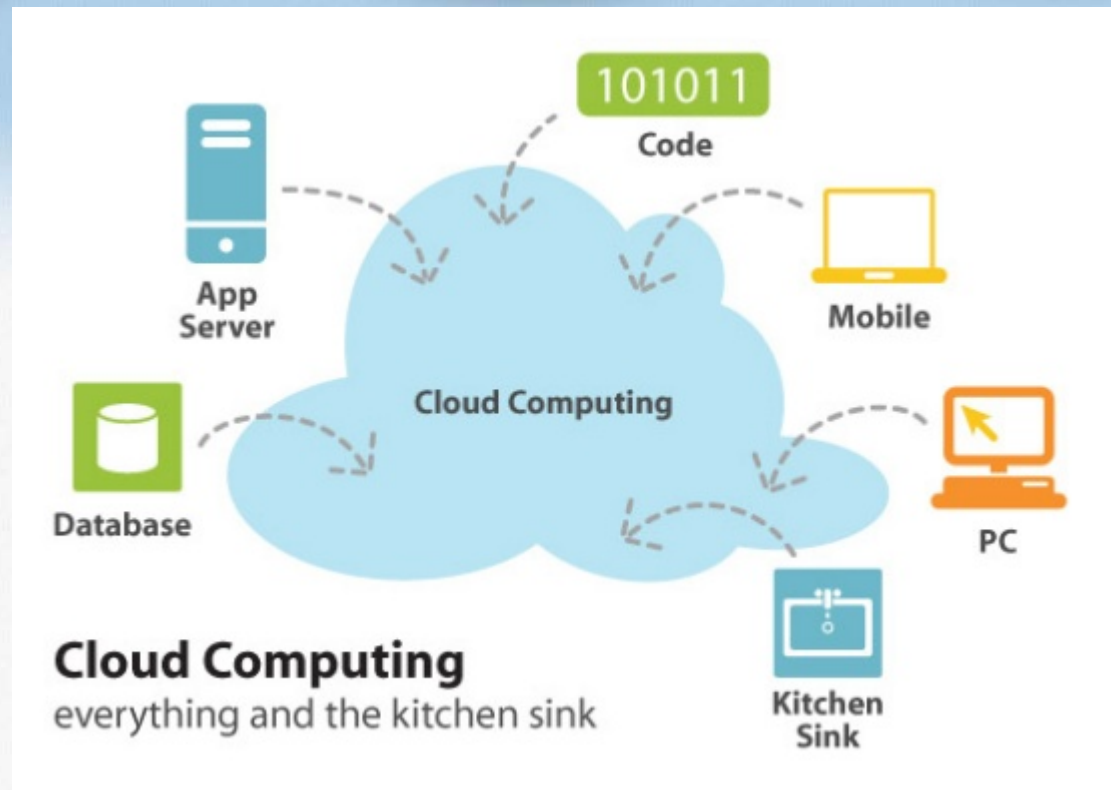


Water as Indispensable resource for our future

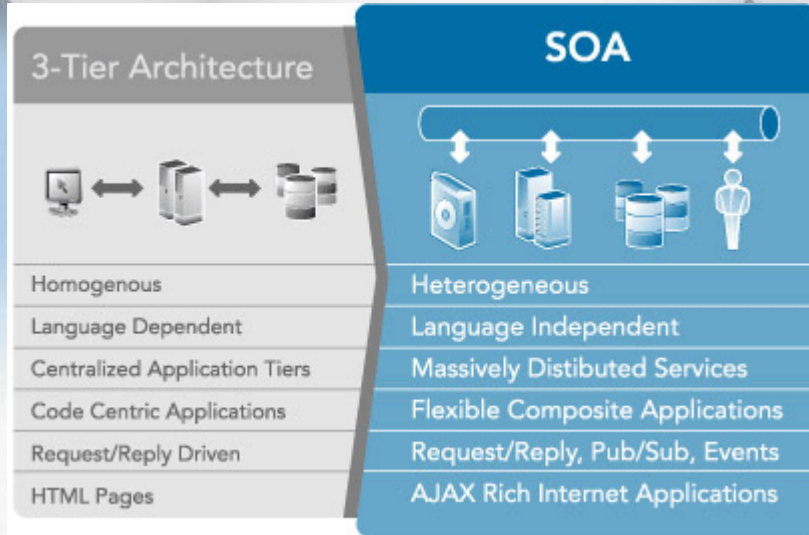
Cloud computing

Cloud is a system that enables data processing, software and access of data services independently of physical location and configuration.

Similar to this concept is the electric grid where users utilize power without understanding the system components.



SOA (Service Oriented Architecture)



Functionality of system based on SOA is in interoperable services that work on different information systems. SOA defines how to integrate heterogeneous application and platform into web based solution.

SOA enables :

- Integration independent of the programming language.
- Components reuse
- Improving the existing systems



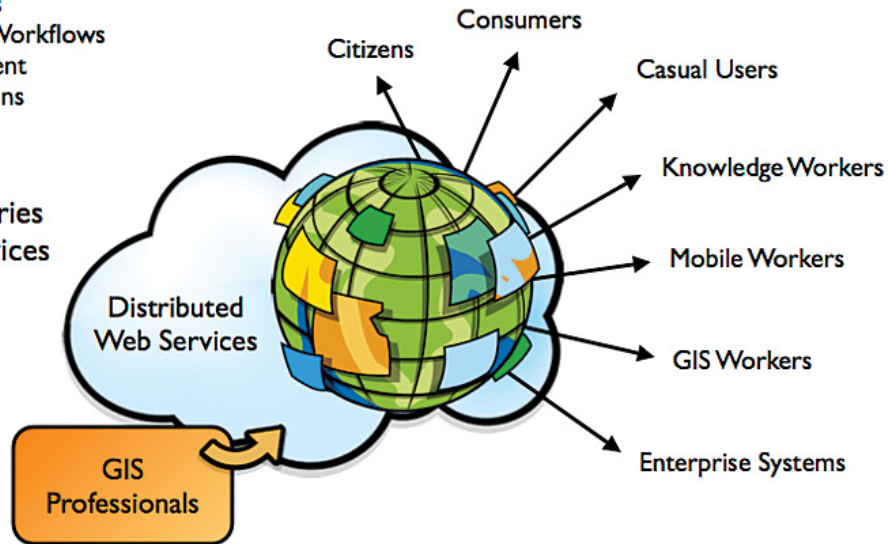
The core components which make up an SOA implementation

Web GIS

Author and Serve Geographic Knowledge

- High-Quality Maps
- 3D Visualizations
- Analysis and Models
- Data Management Workflows
- Authoritative Content
- Rich Web Applications

Constructing libraries
of shared GIS services

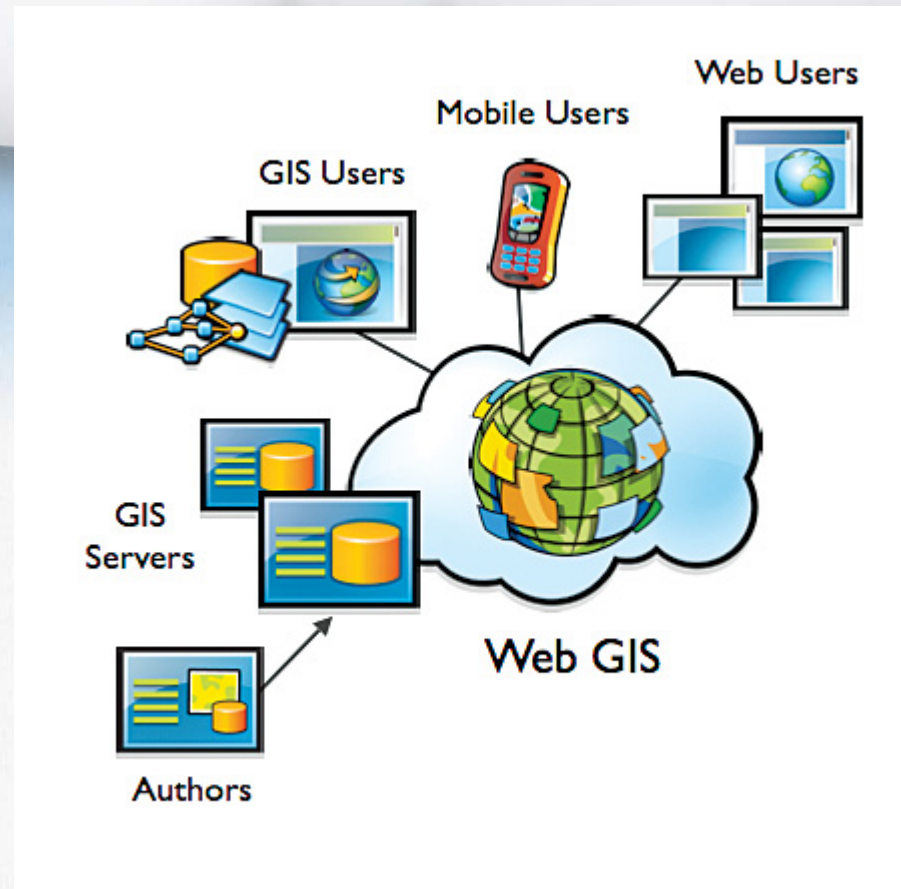


Web Service standards Geospatial web service standards

OGC geospatial web standards:

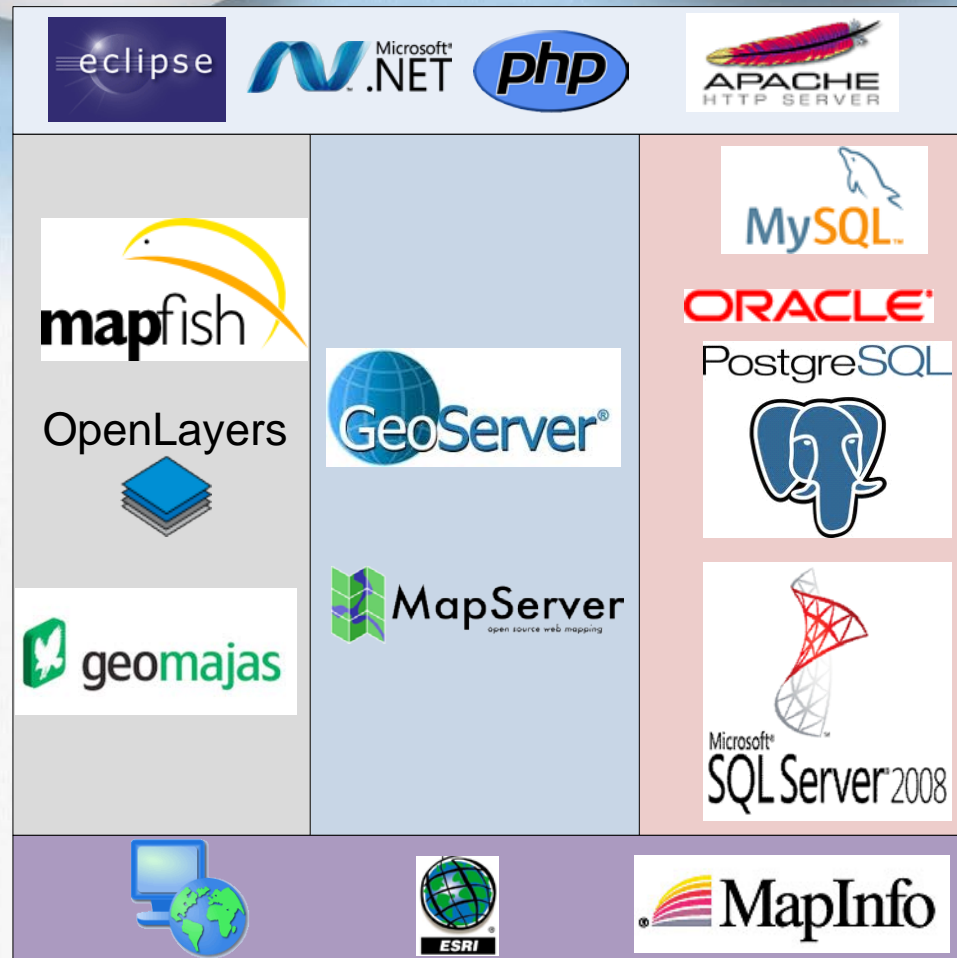
Web Coverage Service (WCS) Web Feature Service (WFS) , Web Coordinate Transformation Service (WCTS) ,Web Map Service (WMS), Web Image Classification Service (WICS)

Web GIS

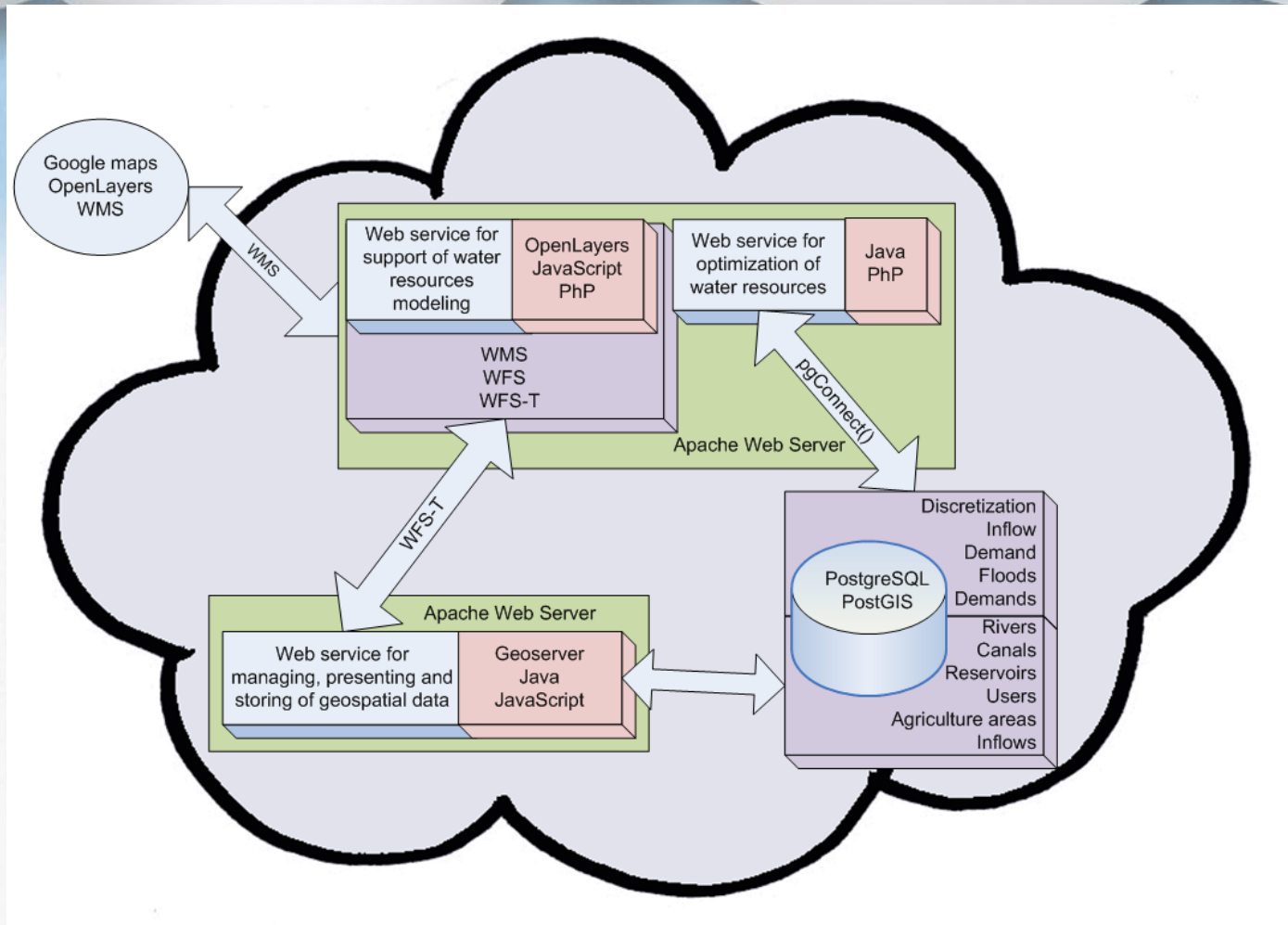


XML (eXtensible Markup Language) is a primary language for coding of data/messages of web services and interoperable structured information.

Software components and technologies



Architecture of the cloud hydroinformation system and web services



Development Cloud hydro information system

Creation of the geospatial relational database HMak

PostgreSQL together with PostGIS for support of standard and geospatial data. Main function of HMak is central database for the web services.

Mapinfo, ArcGIS

6 vector maps layers

- rivers
- canals
- reservoirs
- users
- water inflow,
- agriculture land

The image shows two overlapping windows from a PostgreSQL environment. The background window is pgAdmin III, displaying the 'Object browser' with a tree view of the 'public' schema. The 'Basin_rivers' table is highlighted. The foreground window is the 'Shape File to PostGIS Importer'. It shows the 'Shape File' as 'Rivers.shp'. The 'PostGIS Connection' section has fields for Username (postgres), Password (masked), Server Host (localhost), Port (5433), and Database (Bregalnica). A 'Test Connection...' button shows 'Connection succeeded.'. The 'Configuration' section shows 'Destination Schema' as 'public', 'SRID' as '-1', 'Destination Table' as 'Rivers', and 'Geometry Column' as 'the_geom'. The 'Import Log' at the bottom shows the connection details and 'Connection succeeded.'.

pgAdmin III

Object browser

Schemas (1)

- public
 - Domains (0)
 - FTS Configurations (0)
 - FTS Dictionaries (0)
 - FTS Parsers (0)
 - FTS Templates (0)
 - Functions (780)
 - Sequences (22)
 - Tables (34)
 - Basin_regions
 - Basin_rivers
 - Land_Agriculture
 - Regions
 - blagoj
 - demand
 - flood
 - geometry_columns
 - glavniKanali_polyline
 - godisna izohietska karta1
 - godic(en od na vrne' -sifti
 - granica
 - granica na mkd-sift_1
 - hydrologicalData
 - ico
 - inflow
 - kanali
 - meterologicalStations
 - probno
 - rainfallStations
 - recreation
 - rek1-sift
 - relativna vla'nost-sift

Properties

Property	Value
Name	Basin_rivers
OID	18101
Owner	postgres
Tablespace	pg_default
ACL	
Of type	
Primary key	gid
Rows (estimated)	3
Fill factor	
Rows (counted)	3
Inherits tables	No
Inherited tables count	0

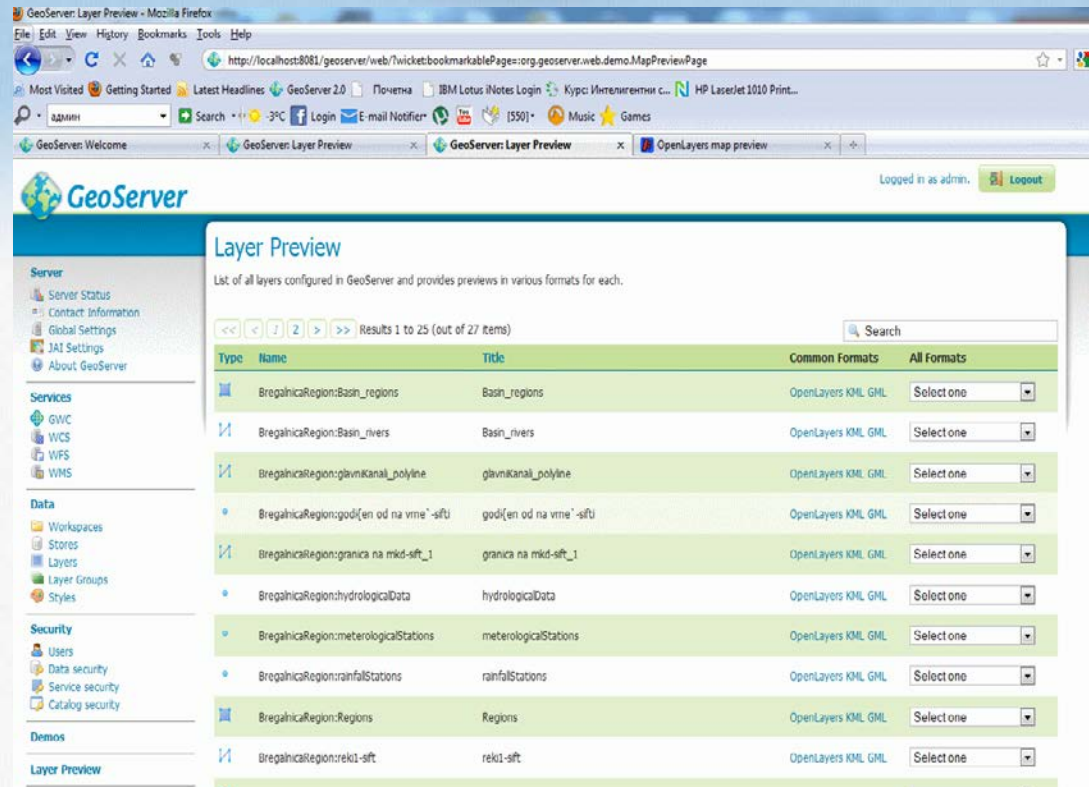
SQL pane

```
-- Table: "Basin_rivers"
-- DROP TABLE "Basin_rivers";
CREATE TABLE "Basin_rivers"
(
gid serial NOT NULL,
id integer,
"name" character varying(50),
the_geom geometry,
CONSTRAINT "Basin_rivers_pkey" PRIMARY KEY (gid),
CONSTRAINT enforce_dims_the_geom CHECK (st_ndims(the_geom) = 2),
CONSTRAINT enforce_geotype_the_geom CHECK (geometrytype(the_geom) = 'POINT' OR geometrytype(the_geom) = 'POLYGON'),
CONSTRAINT enforce_srid_the_geom CHECK (st_srid(the_geom) = -1)
)
WITH (
OIDS=FALSE
)
```

Development Cloud hydro information system

Geoserver

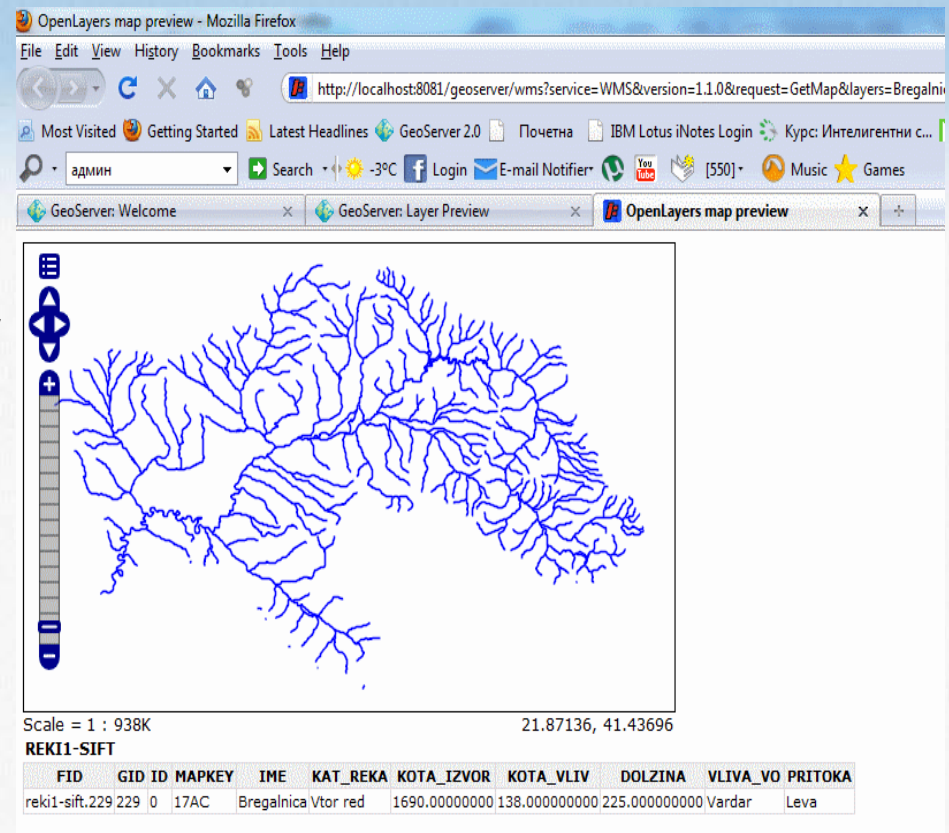
Geoserver is a Java web application that implements OGC standards for WFS, WMS, WMS and integrated web mapping server.



Development Cloud hydro information system

Geoserver

- Geoserver displays web interface for presenting and searching geospatial data
- Geoserver works on Apache web server and presents HMak geospatial data.
- Geoserver is middle layer application between data from HMak and created service for modeling of water resources
- OGC standards
- Distribution and interoperability

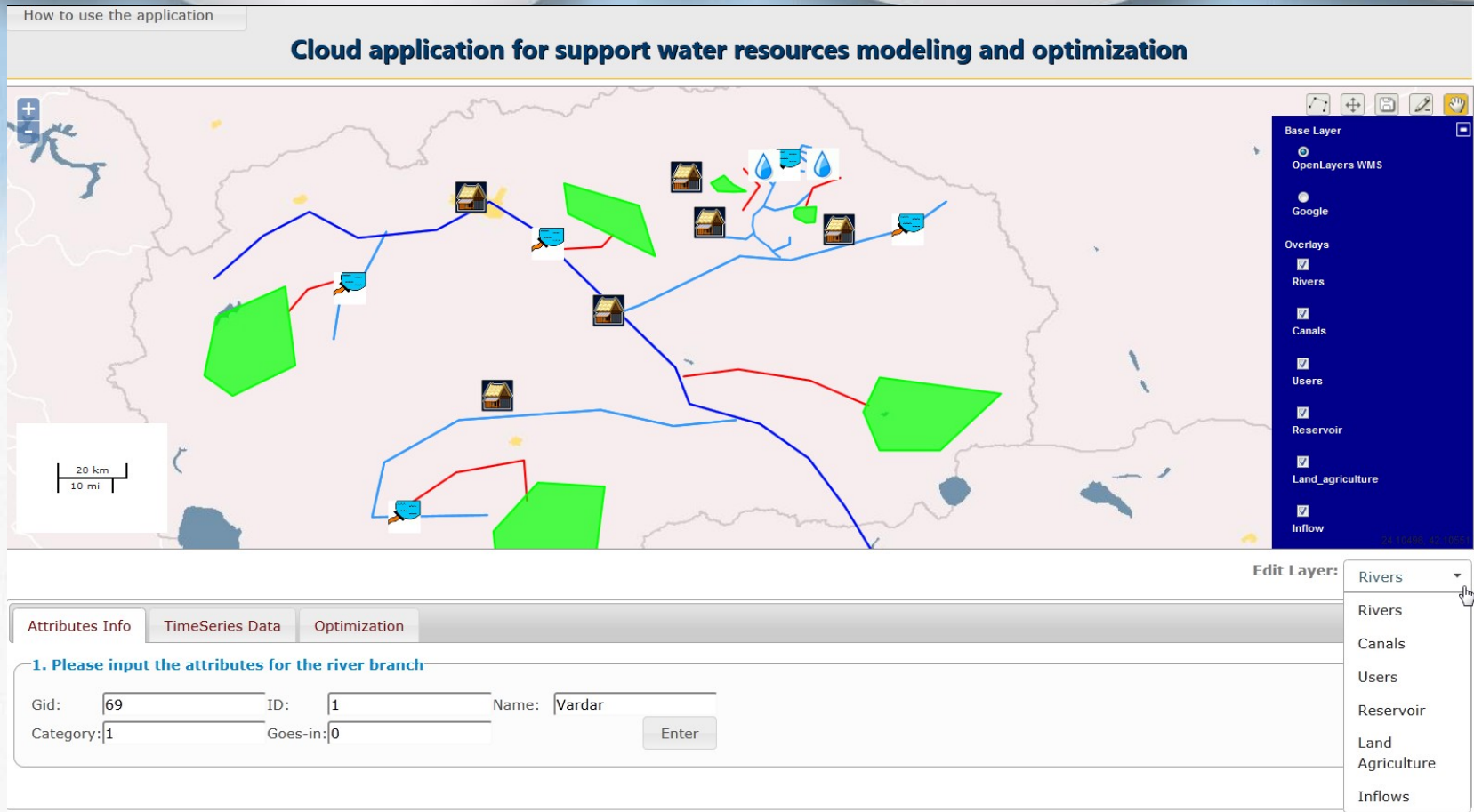


Development of web service for supporting water resources modeling

- Web service is build using OpenLayers library that support OGC standards WMS, WFS and WFS-T.
- Web service is working on Apache web server and it is developed using several programming languages like JavaScript, AJAX, PHP combining service for managing geospatial data Geoserver, database HMak and OpenLayers library.

```
1      function init() {  
2          map = new OpenLayers.Map("map");  
3          var base1= new OpenLayers.Layer.WMS( "OpenLayers  
4              WMS",  
5              "http://vmap0.tiles.osgeo.org/wms/vmap0", layers : 'basic' );  
6          map.addLayer(base1);  
7          var rivers = new OpenLayers.Layer.Vector("rivers-WFS", {  
8              strategies: [new OpenLayers.Strategy.BBOX(), saveStrategy],  
9              protocol: new OpenLayers.Protocol.WFS({  
10                 version: "1.1.0",  
11                 url: "http://localhost:8081/geoserver/wfs?",  
12                 featureType: "rivers",  
13                 featureNS: "http://www.delipetrov.com",  
14                 srsName: "EPSG:4326"  
15             })  
16             });  
17          map.addLayer(rivers);
```

Development of web service for supporting water resources modeling



Development of web service for supporting water resources modeling

Entering new polilyne (comunication in XML)

```
$xml = '<wfs:Transaction xmlns:wfs="http://www.opengis.net/wfs" service="WFS"
version="1.1.0" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance"><wfs:Insert><feature:Regions
xmlns:feature="http://www.delipetrov.com"><feature:the_geom><gml:MultiSurface
xmlns:gml="http://www.opengis.net/gml"
srsName="EPSG:4326"><gml:surfaceMember><gml:Polygon><gml:exterior><gml:Li
nearRing><gml:posList>23.36455078125    41.398999023437    23.095385742187
41.344067382812    23.172290039062    41.135327148437    23.743579101562
41.283642578125    23.36455078125
41.398999023437</gml:posList></gml:LinearRing></gml:exterior></gml:Polygon></
gml:surfaceMember></gml:MultiSurface></feature:the_geom></feature:Regions></wfs:
Insert></wfs:Transaction>';
```

Development of service for optimization of water resources

$$p_h^* = \arg \max_{p_h} \sum_{t=0}^{h-1} \gamma^t g_t(x_t, u_t, \varepsilon_{t+1})$$

$$x_{t+1} = f_t(x_t, u_t, \varepsilon_{t+1})$$

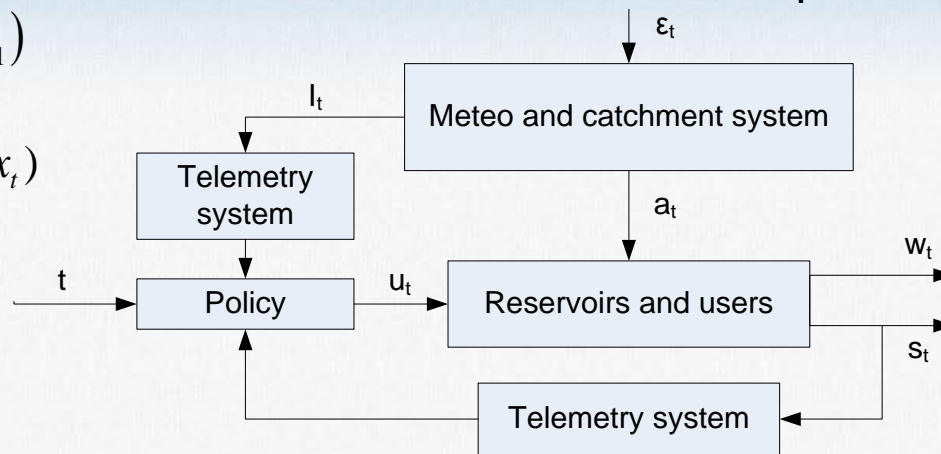
$$m_t(x_t) = u_t \in U_t(x_t)$$

$$\varepsilon_{t+1} = \phi(\cdot | x_t, u_t)$$

x_0 е дадено

$$p_h = \{m_t(\cdot); t = 0, \dots, h-1\}$$

Dynamic programming (DP) and latter Stochastic dynamic programming (SDP) are one of the most used methods for optimal reservoir operation.

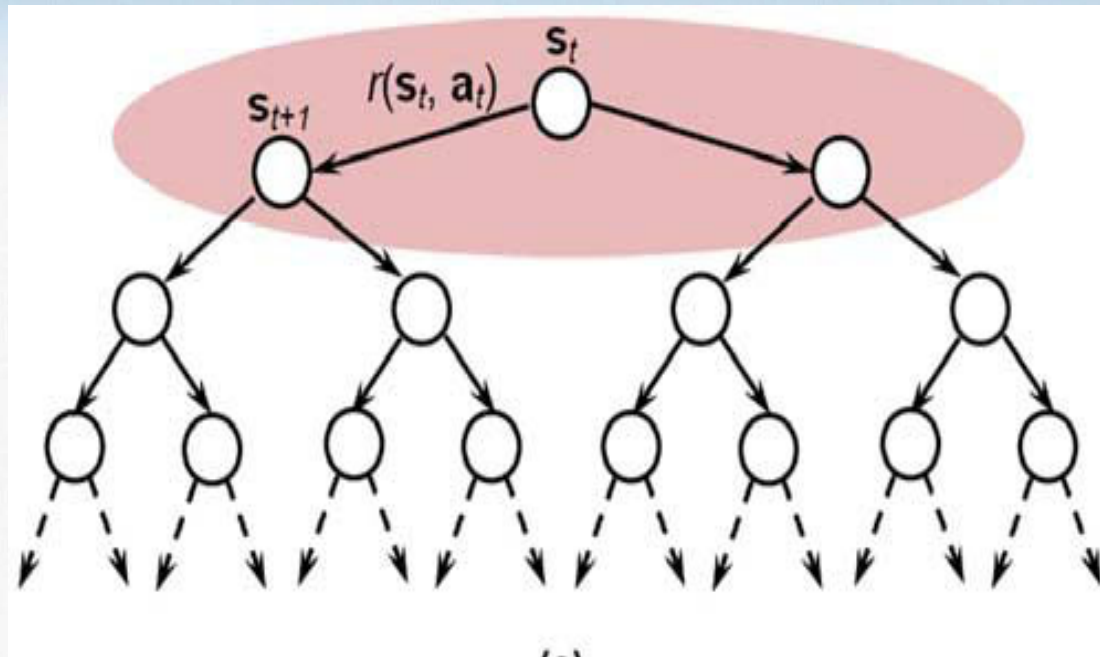


DP and SDP have two major limitation (Bellman 1957), 1Curse of dimensionality 2) Curse of modelling) and are difficult to be used in practical application of complex water systems.

Development of service for optimization of water resources

Solution of the problem is calculated recursively with Bellman equation:

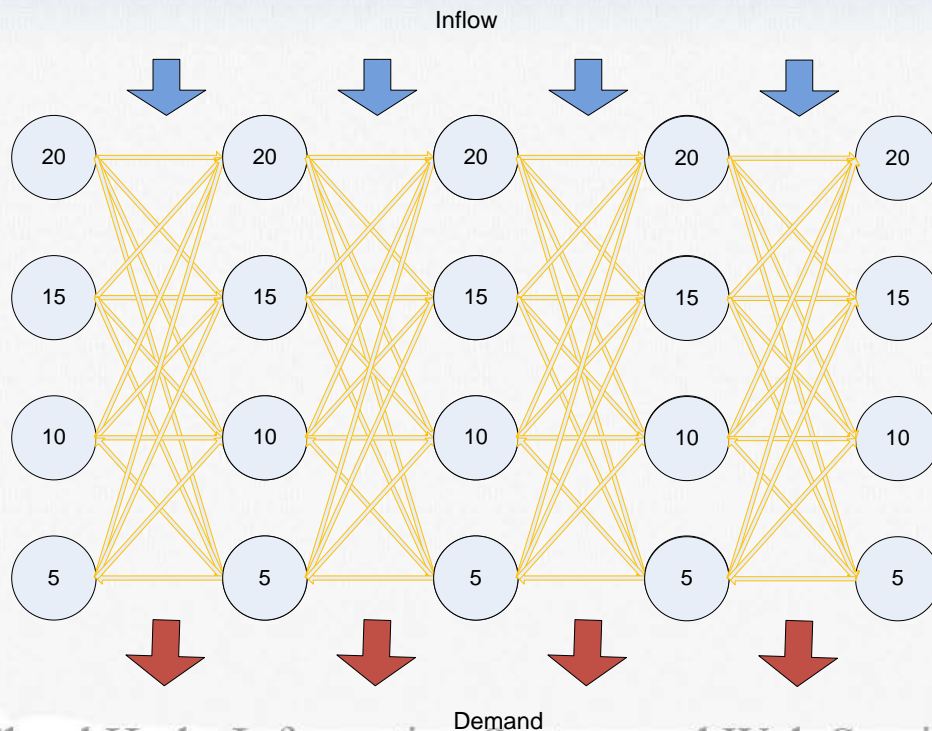
$$Q_t(x_t, u_t) = g_t(x_t, u_t, \varepsilon_{t+1}) + \gamma \max_{u_{t+1}} Q_{t+1}(x_{t+1}, u_{t+1})$$



$$m_t^*(x_t) = \arg \max_{u_t} Q_t^*(x_t, u_t)$$

Development of service for optimization of water resources

Inflow	Demand	Flood	Recreation	Discretization
Int TS Double Inflow	Int TS Double Demand Double Weight	Int TS Double Flood Double Weight	Int TS Double Recreation Double Weight	Double Discretization



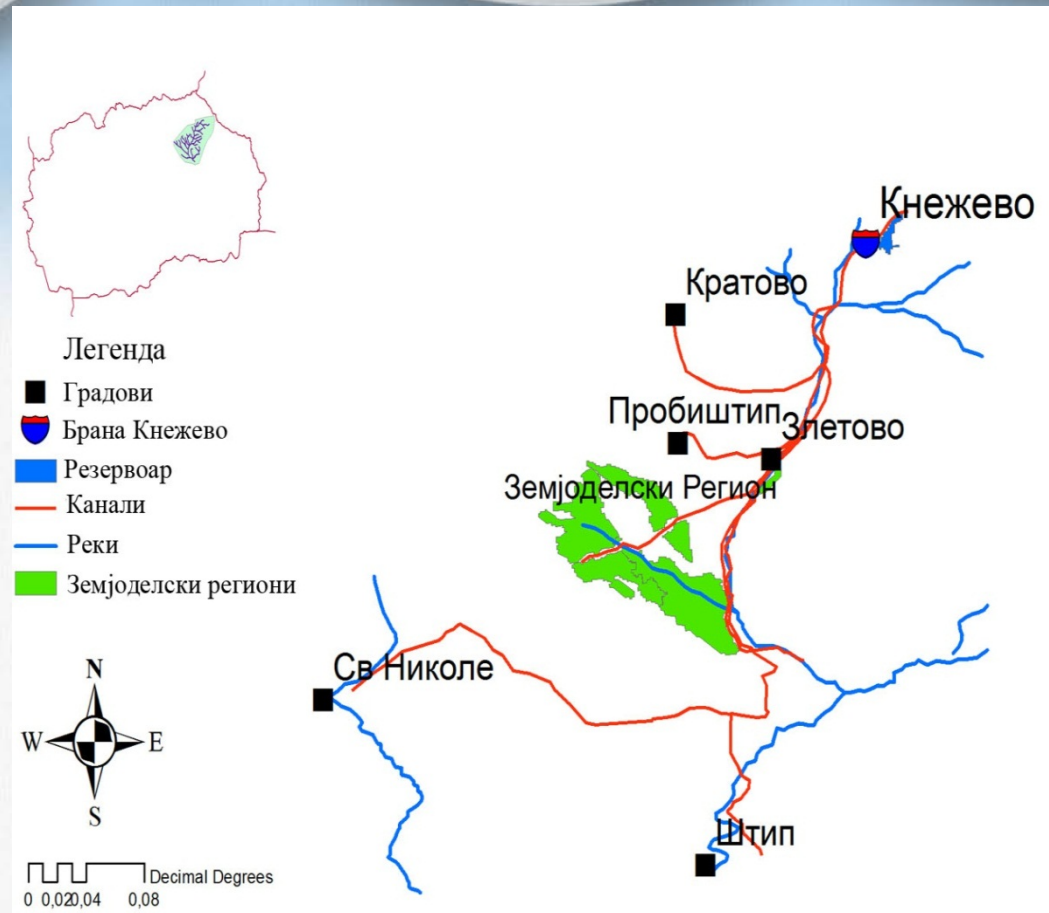
Prototype application DP is based on the algorithm of dynamic programming developed in Java using Eclipse.

Loucks, D. P., Van Beek E., Stedinger J. R., Dijkman J. P. M. and Villars M. T. (2005). *Water resources systems planning and management: an introduction to methods, models and applications*, Paris: UNESCO. pp. 90 - 113

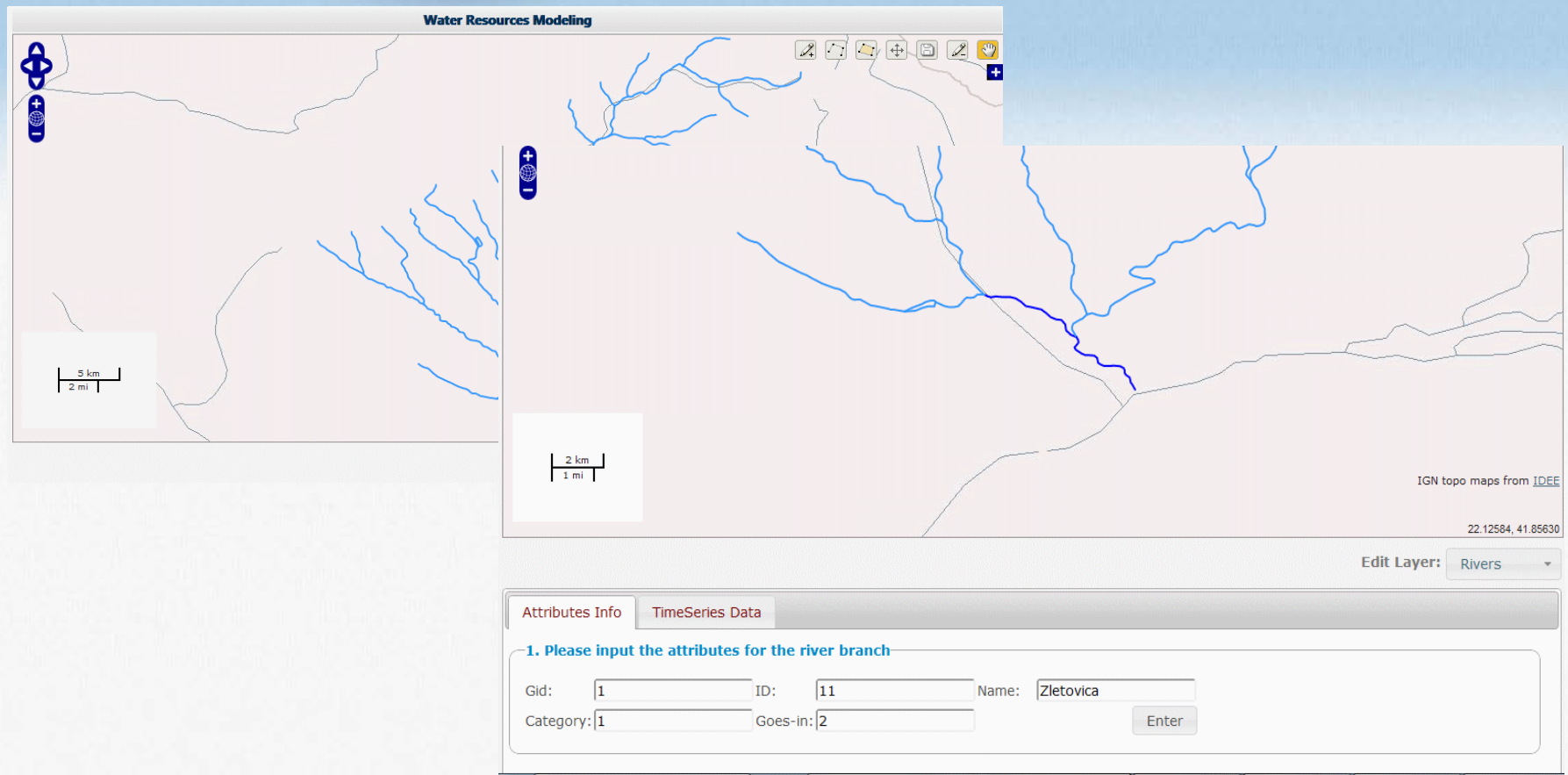
$$\min \sum_{t=0}^T TSD_t$$

Cloud hydro information system and web services implementation in HS Zletovica

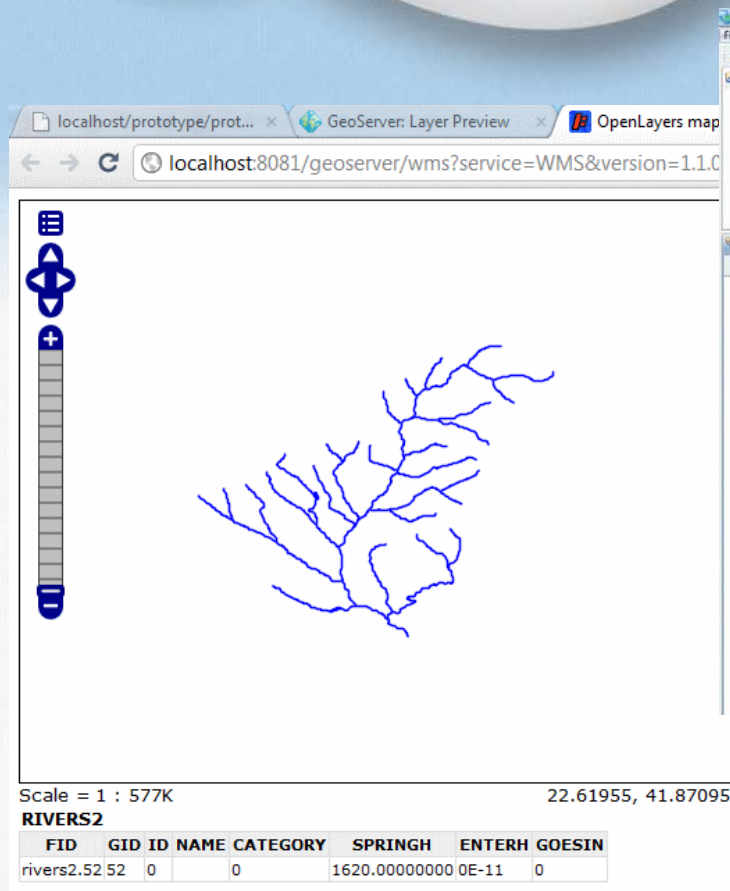
Hydro system Zletovica is in north east part of the Republic of Macedonia covering around 223.000 ha.



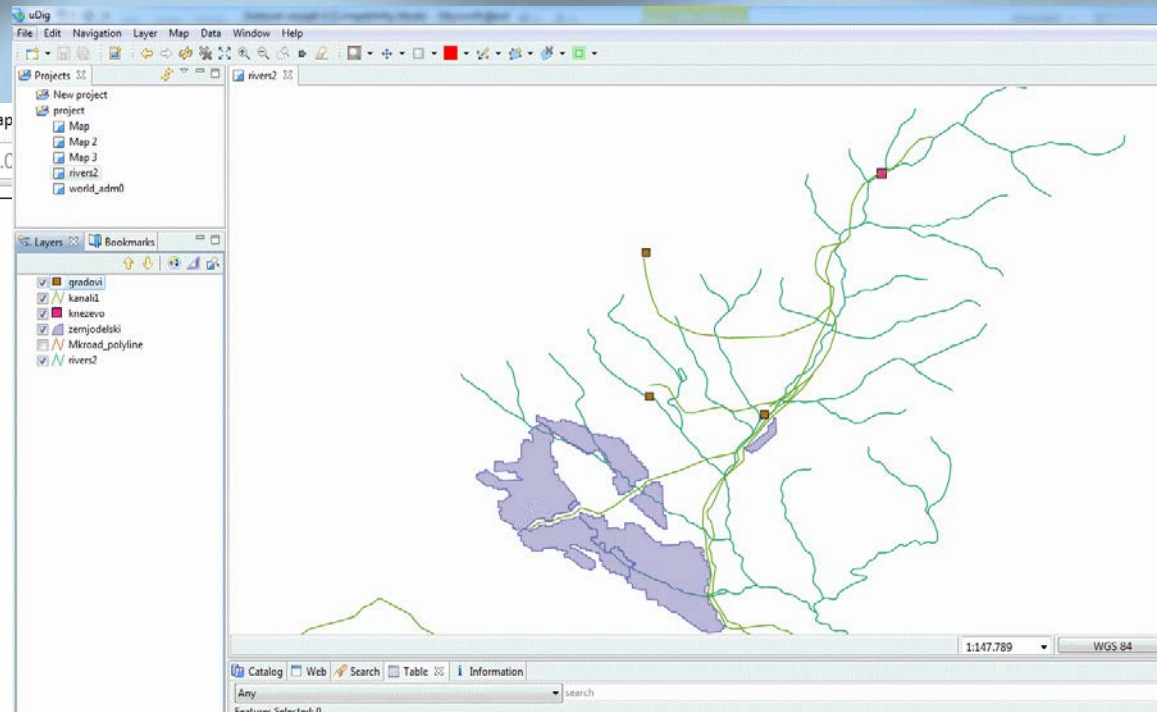
Cloud hydro information system and web services implementation in HS Zletovica



Cloud hydro information system and web services implementation in HS Zletovica



Geoserver

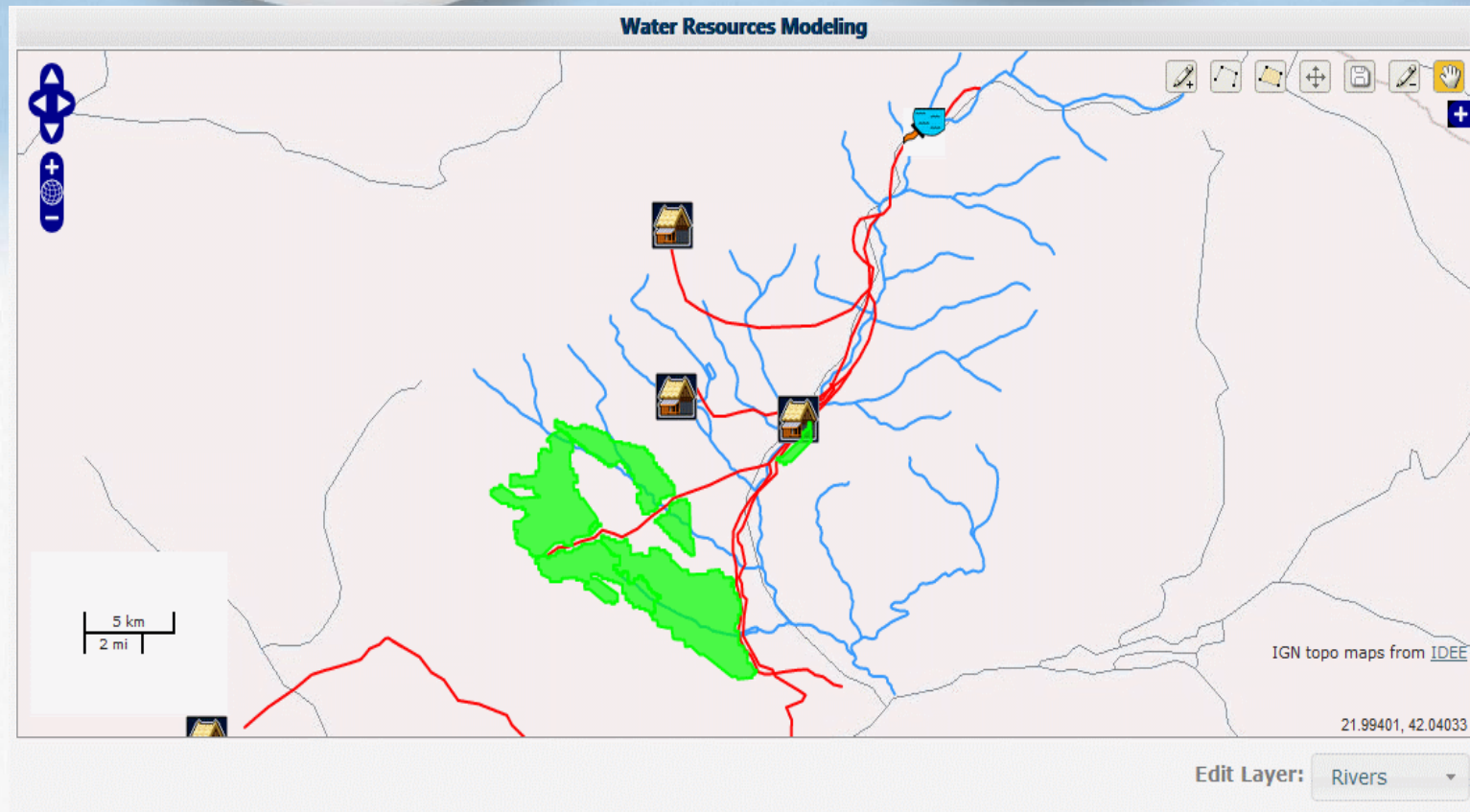


Desktop application

uDig

- WFS
- WMS
- And others

Cloud hydro information system and web services implementation in HS Zletovica



Web service for water resources optimization

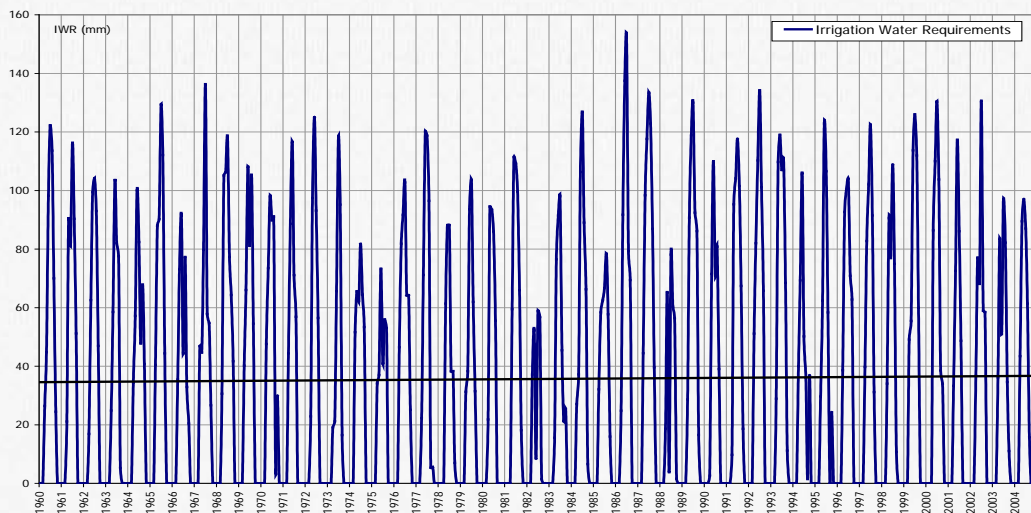
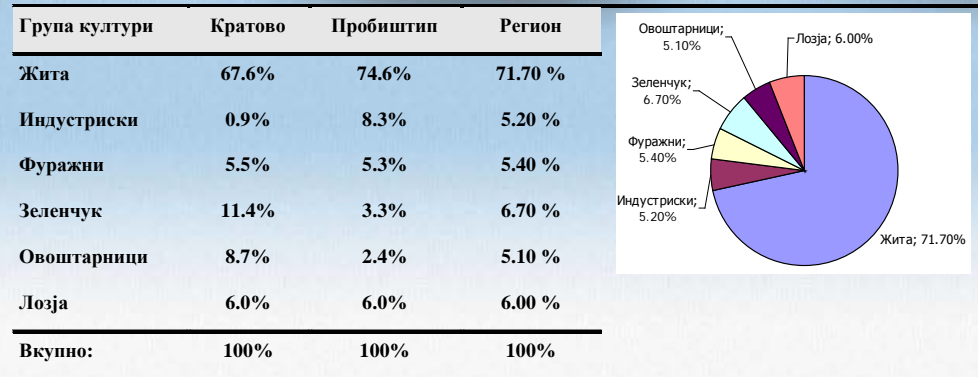
- Providing drinking water for municipalities Kratovo, Probistip, Zletovo, Stip, Karbinci, Sveti Nikole, Karbinci and Stip.
- Providing water for the agriculture for 3100 ha.
- Generating electrical power with three hydro power generators
- Biological minimum for Zletovica river

	Kratovo	Probistip	Stip	Sv. Nikole	Total
Average	0,11	0,13	0,50	0,09	0,72
Months	m3/s	m3/s	m3/s	m3/s	
1	0,10	0,11	0,43	0,08	0,621
2	0,10	0,12	0,47	0,09	0,681
3	0,11	0,10	0,39	0,07	0,559
4	0,11	0,13	0,50	0,09	0,719
5	0,11	0,13	0,52	0,09	0,742
6	0,12	0,15	0,59	0,11	0,845
7	0,12	0,15	0,58	0,11	0,840
8	0,12	0,15	0,58	0,11	0,840
9	0,12	0,18	0,70	0,13	1,006
10	0,11	0,13	0,51	0,09	0,738
11	0,10	0,09	0,37	0,07	0,531
12	0,10	0,09	0,37	0,07	0,531

Water demand for municipalities

Web service for water resources optimization

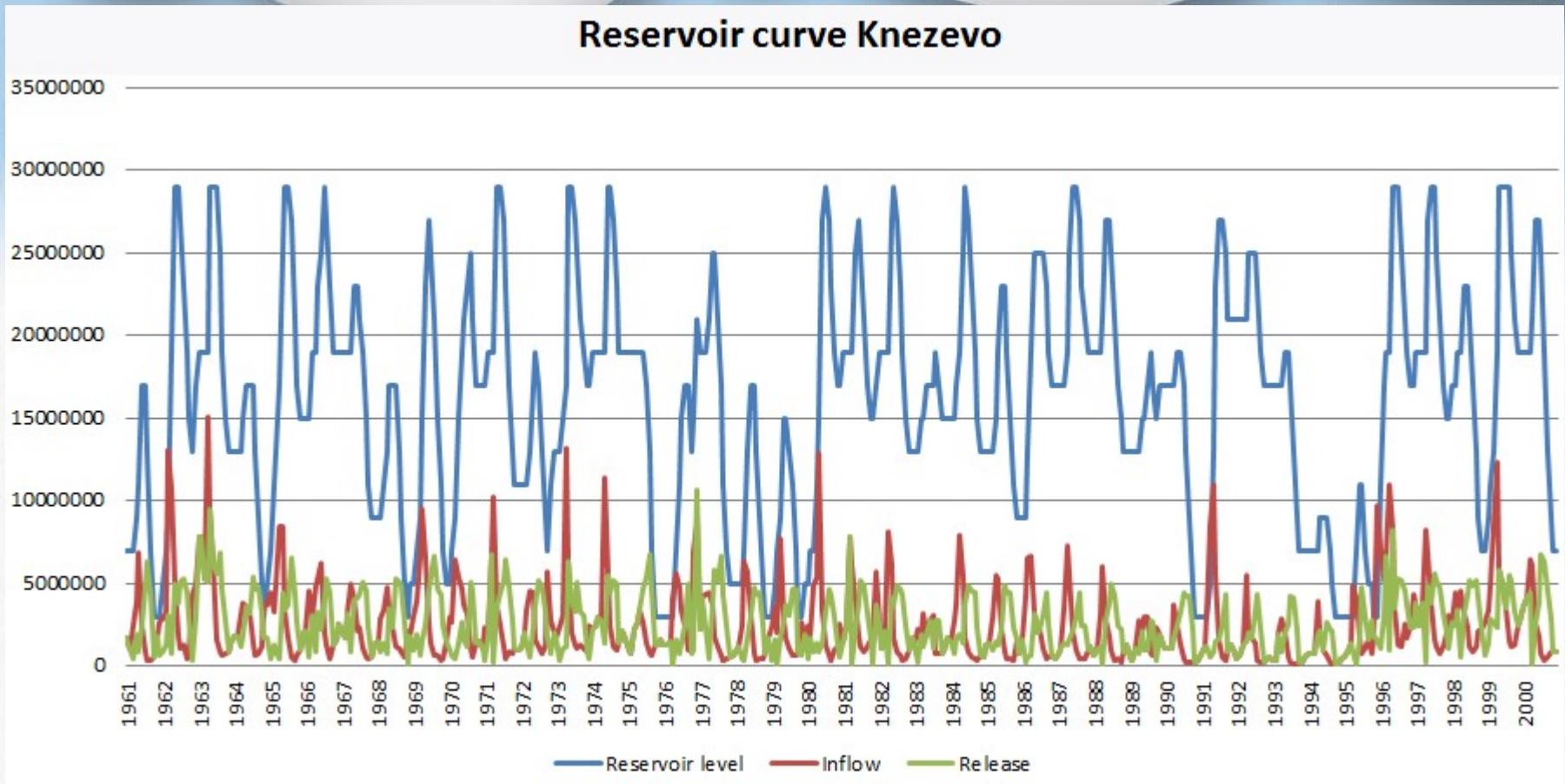
Water for agriculture



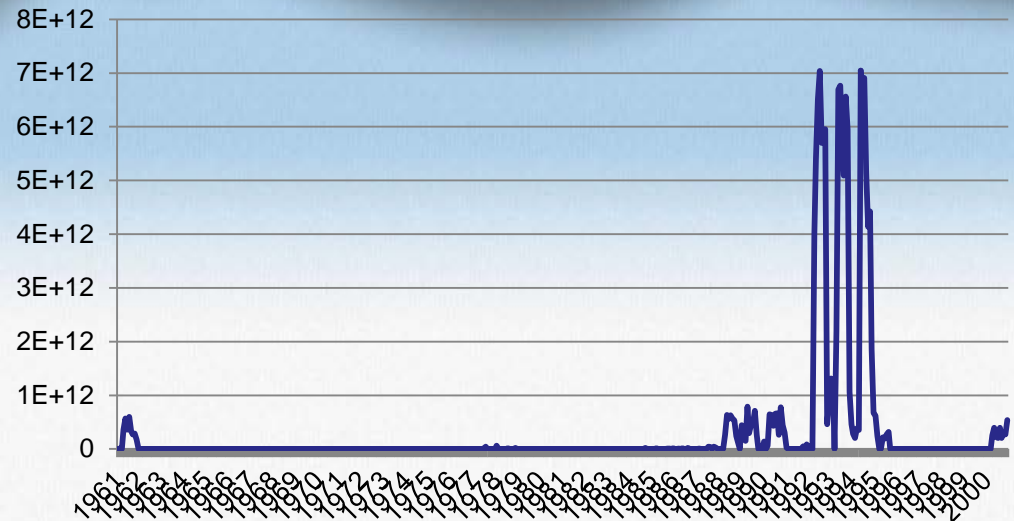
Web service for water resources optimization

Month	Floods(m ³)	Weight factor of floods	Recreation (m ³)	Weigh factor recreation		
1	28000000		1	3000000	0.7	0
2	27000000		1	3000000	0.7	1
3	25000000		1	3000000	0.7	2
4	25000000		1	3000000	0.7	3
5	27000000		1	3000000	0.7	4
6	29000000		1	6000000	0.7	5
7	30000000		1	6000000	0.7	6
8	30000000		1	6000000	0.7	7
9	29000000		1	3000000	0.7	--
10	25000000		1	3000000	0.7	3000000
11	25000000		1	3000000	0.7	60
12	28000000		1	3000000	0.7	0
Input data for flood and recreation of the first simulation						

Web service for water resources optimization



Web service for water resources optimization



**Average water quantity in the 18.072.917
reservoir (m³)**

Average reservoir inflow (m³)	2.539.221
---	-----------

Average reservoir release (m³)	2.539.221
--	-----------

Total TDK	1,43*10 ¹⁴
------------------	-----------------------

Overall results of the first simulation and optimization

Conclusion

- Open Source Components
- System advantages over previous technologies are:
 - Accessibility (Anywhere)
 - Availability (Anytime)
 - Flexibility
 - Supporting distributed computer resources
 - Scalable computational power
- Ultimate internet based collaboration platform
- Tested with several users simultaneously using the web services
- Further system development can include additional water related data, urbanization, population growth, infrastructure, etc. and creation of additional web services.
- Optimization of water resources with using Reinforcement Learning, Decision trees, Artificial Neural Network and others
- The cloud computing framework is build, tested and ready for improving the existing or developing new web services



THANK YOU 😊
FOR YOUR ATTENTION

<http://79.99.60.36/prototype/>

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